

INTERNATIONAL STANDARD



HORIZONTAL PUBLICATION

**Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings –
Part 1: Requirements for measuring instruments.**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 1: Requirements for measuring instruments

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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 61786-1 edition 1.1 contains the fifth edition (2013-12) [documents 106/292/FDIS and 106/298/RVD] and its amendment 1 (2024-07) [documents 106/647/FDIS and 106/655/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61786-1 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

The first editions of IEC 61786-1 and IEC 61786-2 replace IEC 61786:1998. Part 1 deals with measuring instruments, and Part 2 deals with measurement procedures. The content of the standard was revised in order to give up-to-date and practical information to the user.

It has the status of a horizontal standard in accordance with IEC Guide 108.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61786 series, published under the general title *Measurement of DC magnetic fields and AC magnetic and electric fields from 1 Hz to 100 kHz with regard to exposure of human beings*, can be found on the IEC website.

The committee has decided that the contents of this document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
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MEASUREMENT OF DC MAGNETIC, AC MAGNETIC AND AC ELECTRIC FIELDS FROM 1 Hz TO 100 kHz WITH REGARD TO EXPOSURE OF HUMAN BEINGS –

Part 1: Requirements for measuring instruments

1 Scope

This part of IEC 61786 provides guidance for measuring instruments used to measure the field strength of quasi-static magnetic and electric fields that have a frequency content in the range 1 Hz to 100 kHz and with DC magnetic fields to evaluate the exposure levels of the human body to these fields.

Sources of fields include devices that operate at power frequencies and produce power frequency and power frequency harmonic fields, as well as devices that produce fields within the frequency range of this document, including devices that produce static fields, and the earth's static magnetic field. The magnitude ranges covered by this standard are 0,1 μ T to 200 mT in AC (1 μ T to 10 T in DC) and 1 V/m to 50 kV/m for magnetic fields and electric fields, respectively.

When measurements outside this range are performed, most of the provisions of this standard will still apply, but special attention should be paid to specified uncertainty and calibration procedures.

Specifically, this standard

- defines terminology;
- identifies requirements on field meter specifications;
- indicates methods of calibration;
- defines requirements on instrumentation uncertainty;
- describes general characteristics of fields;
- describes operational principles of instrumentation.

NOTE Measurement methods that achieve defined goals pertaining to assessment of human exposure are described in IEC 61786-2

Sources of uncertainty during calibration are also identified. In regard to electric field measurements, this standard considers only the measurement of the unperturbed electric field strength at a point in free space (i.e. the electric field prior to the introduction of the field meter and operator) or above conducting surfaces.

This horizontal standard is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 108.

One of the responsibilities of a technical committee is, wherever applicable, to make use of horizontal standards in the preparation of its publications. The contents of this horizontal standard will not apply unless specifically referred to or included in the relevant publications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For

undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) - Part 4-3 : Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

Guide 108, *Guidelines for ensuring the coherency of IEC publications – Application of horizontal standards*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE 1 Internationally accepted SI-units are used throughout the standard.

NOTE 2 For other units, see Annex G.

NOTE 3 Throughout this standard, the words "magnetic flux density" and "magnetic field" will be considered synonymous.

3.1 Meters

3.1.1

measuring instrument

device intended to be used to make measurements, alone or in conjunction with supplementary devices

[SOURCE: IEC 60050-300:2001, 311-03-01]

3.1.2

field meter

meter designed to measure electric, magnetic and electromagnetic fields

Note 1 to entry: Field meters usually consist of three parts: the probe, the detector circuit and the display.

**3.1.3
probe**

input device of a measuring instrument, generally made as a separate unit and connected to it by means of a flexible cable, which transmits the measurand in a suitable form

Note 1 to entry: A probe can be composed of one or several sensors.

[SOURCE: IEC 60050-300:2001, 313-09-11, modified – a note to entry has been added.]

**3.1.4
detector**

device for discerning the existence or variations of waves, oscillations or signals, usually for extracting information conveyed.

EXAMPLES Peak detector, rms detector

[SOURCE: IEC 60050-702:1992, 702-09-39, modified – the examples are different.]

**3.1.5
free-body meter**

meter that measures the unperturbed electric field strength at a point above the ground and is supported in space without conductive contact to ground

**3.1.6
fluxgate magnetometer**

instrument designed to measure magnetic fields by making use of the non-linear magnetic characteristics of a probe or sensing element that has a ferromagnetic core

**3.1.7
ground reference meter**

meter that measures the electric field at or close to the surface of the ground, frequently implemented by measuring the induced current or charge oscillating between an isolated electrode and ground.

Note 1 to entry: The isolated electrode is usually a plate located at ground level or slightly above the ground surface.

**3.1.8
survey meter**

lightweight battery-operated meter that gives a real time read-out and that can be held conveniently by hand in order to conduct survey type measurements in different locations

**3.1.9
coil probe**

magnetic flux density sensor comprised of a coil of wire that produces an induced voltage proportional to the time derivative of the magnetic field

**3.1.10
Hall effect probe**

magnetic flux density sensor containing an element exhibiting the Hall effect to produce a voltage proportional to the magnetic flux density

3.2 Meter characteristics

**3.2.1
crest factor**

ratio of the maximum absolute value of an alternating quantity to its root-mean-square value

[SOURCE: IEC 60050-103:2009, 103-14-57, modified – the original term was "peak factor" and the note has been deleted.]

3.2.2**crosstalk**

the appearance of undesired energy in a channel, owing to the presence of a signal in another channel, caused by, for example induction, conduction or non-linearity

[SOURCE: IEC 60050-722:1992, 722-15-03]

3.2.3**frequency response**

for a linear time-invariant system with a sinusoidal input variable in steady state the ratio of the phasor of the output variable to the phasor of the corresponding input variable, represented as a function of the angular frequency ω

[SOURCE: IEC 60050-351:2006, 351-24-33, modified – the note in the original has been deleted.]

3.2.4**isotropy of the probe**

a measure of the degree to which the response of a field probe is independent of the polarization and direction of propagation of the incident field

3.2.5**pass-band**

frequency band throughout which the attenuation is less than a specified value

[SOURCE: IEC 60050-151:2001, 151-13-52]

3.2.6**root-mean-square value****rms value**

1) for n quantities x_1, x_2, \dots, x_n , positive square root of the mean value of their squares:

$$X_q = \left[\frac{1}{n} (x_1^2 + x_2^2 + \dots + x_n^2) \right]^{1/2} \quad (1)$$

2) for a quantity x depending of a variable t , positive square root of the mean value of the square of the quantity taken over a given interval $[t_0, t_0 + T]$ of the variable

$$X_q = \left[\frac{1}{T} \int_{t_0}^{t_0+T} [x(t)]^2 dt \right]^{1/2} \quad (2)$$

Note 1 to entry: The rms value of a periodic quantity is usually taken over an integration interval the range of which is the period multiplied by a natural number

[SOURCE: IEC 60050-103:2009, 103-02-02, modified – the second note in the original definition has been deleted.]

3.3 Field characteristics**3.3.1****unperturbed field**

field at a point that would exist in the absence of persons or movable objects

3.3.2

nearly uniform field

field in area where the resultant field over the cross-sectional area of the probe does not change more than 1%

3.3.3

quasi-static field

field that satisfies the condition $f \ll \frac{c}{l}$ (i.e. wavelength $\gg l$), where f is the frequency of the field, c is the speed of light, and l is a characteristic dimension of the measurement geometry, e.g. the distance between the field source and the measurement point

Note 1 to entry: Power frequency magnetic and electric fields near power lines and appliances are examples of quasi-static fields.

3.3.4

resultant field

field given by the expression

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2} \quad (3)$$

where F_x , F_y , and F_z are the rms values of the three orthogonal field components,

or by the expression

$$F_R = \sqrt{F_{\max}^2 + F_{\min}^2} \quad (4)$$

where F_{\max} and F_{\min} are the rms values of the semi-major and semi-minor axes of the field ellipse, respectively.

Note 1 to entry: The resultant F_R is always $\geq F_{\max}$. If the field is linearly polarized, $F_{\min} = 0$ and $F_R = F_{\max}$. If the field is circularly polarized, $F_{\max} = F_{\min}$ and $F_R \approx 1,41 F_{\max}$.

3.4 Measurements

3.4.1

correction factor

numerical factor by which the uncorrected result of a measurement is multiplied to compensate for a known error

Note 1 to entry: Since the known error cannot be determined perfectly, the compensation cannot be complete.

3.4.2

coverage factor

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: For a quantity z described by a normal distribution with expectation μ_z and standard deviation σ , the interval $\mu_z \pm k\sigma$ encompasses 68,27 %, 95,45 % and 99,73 % of the distribution for a coverage factor $k = 1, 2$ and 3, respectively.

3.4.3

scale factor

factor by which the instrument reading is multiplied to obtain its input quantity

3.4.4

standard uncertainty

uncertainty of the result of a measurement expressed as a standard deviation

3.4.5**uncertainty of calibration**

parameter, associated with the result of a calibration, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: Uncertainty of calibration generally comprises many components. Some of these components may be estimated on the basis of the statistical distribution of the results of series of measurements, and can be characterized by experimental standard deviations. Estimates of other components can be based on experience or other information.

4 Symbols

| | |
|----------------------|---|
| a | = radius of coil probe; radius of spherical electric field probe |
| $2a, 2b$ | = side dimensions of rectangular coil |
| \mathbf{B} | = magnetic flux density vector |
| B_0 | = amplitude of alternating magnetic field |
| B_R | = resultant magnetic field |
| B_z | = axial magnetic flux density |
| C | = stray capacitance of coil probe |
| d | = spacing of parallel plates; distance from electromagnetic field source; spacing of Helmholtz coils |
| \mathbf{D} | = electric displacement vector |
| E | = electric field strength |
| E_0 | = uniform electric field strength |
| F_{\max}, F_{\min} | = rms values of semi-major and semi-minor axes of field ellipse |
| I | = current to magnetic field coils |
| L | = inductance of coil probe |
| N | = number of turns of wire (magnetic field coil system) |
| Q | = induced charge |
| r | = distance between magnetic field source and measurement location; resistance of coil probe and leads |
| R | = approximate input impedance of detector circuit (magnetic field meter); radius of Helmholtz coils |
| S | = electrode surface area (electric field meter) |
| t | = time |
| T | = period of periodic signal |
| V | = voltage |
| Z | = impedance in current injection circuit |
| λ | = wave length |
| ε_0 | = permittivity of free space |
| μ_0 | = permeability of free space |
| ϕ | = magnetic flux |
| ω | = angular frequency of alternating field |